Waves, Bubbles, Noise, and Underwater Communications

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LONG-TERM GOALS

The long-term goals are to (1) investigate and understand the role of bubbles in the upper ocean on the generation of ambient noise and their effect on the performance of underwater communications systems, (2) measure and model the scattering of sound by surface gravity waves in shallow and very shallow water to better understand their impact on the performance of Doppler sonar and underwater communications systems, and (3) study the performance of acoustic vectors sensors in very shallow water.

OBJECTIVES

There have been 3 main objectives over the past 12 months. The first obective has been to indentify and model the mechanism responsible for the generation of sound by fragmenting bubbles. Bubble fragmentation is thought to be an important physical process controlling air entrainment in breaking waves, which determines the numbers and sizes of bubbles in the upper ocean during breaking wave conditions and generates underwater ambient noise. Making the connection between noise production and bubble creation rates will help quantify scattering conditions at the ocean surface through ambient noise measurements. The second objective was to participate in the Surface Processes and Acoustic Communications Experiment 08 (SPACE08) at the Martha's Vineyard Coastal Observatory (MVCO) at Woods Hole Oceanographical Institution. The third objective was to deploy and collect data from an array of vector sensors in the shallow waters north of Scripps Pier on La Jolla Shores Beach.

APPROACH

The technical approach over the past year has focused heavily on laboratory and at-sea field work. A series of laboratory studies have been undertaken to observe the acoustic excitation of bubbles at the moment of their formation and the scattering of sound from scale model surface gravity waves. Two field experiments, one in the surf zone off La Jolla Shores Beach and another at MVCO, have been undertaken to study the impact of surface processes on underwater communications signals and to investigate the performance of an 8-element array of Wilcoxon VS205 vector sensors. Finally, a scale model tank experiment to test an acoustic model for surface gravity wave focusing was conducted.

WORK COMPLETED

Work has been completed on all three topic areas. In the area of bubbles and ambient noise, the bubble excitation model described in the 2007 ONR report (Deane and Czeski 2008) has been applied to the acoustic emissions of bubbles fragmenting in fluid turbulence. This problem is particularly important

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14. ABSTRACT
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to upper ocean boundary layer physics when there are white caps fragmenting bubbles at the ocean surface. The neck collapse model has been used to predict the peak pressure radiated by fragmenting bubbles, the results of which is shown in figure 1, compared with data from an experiment.

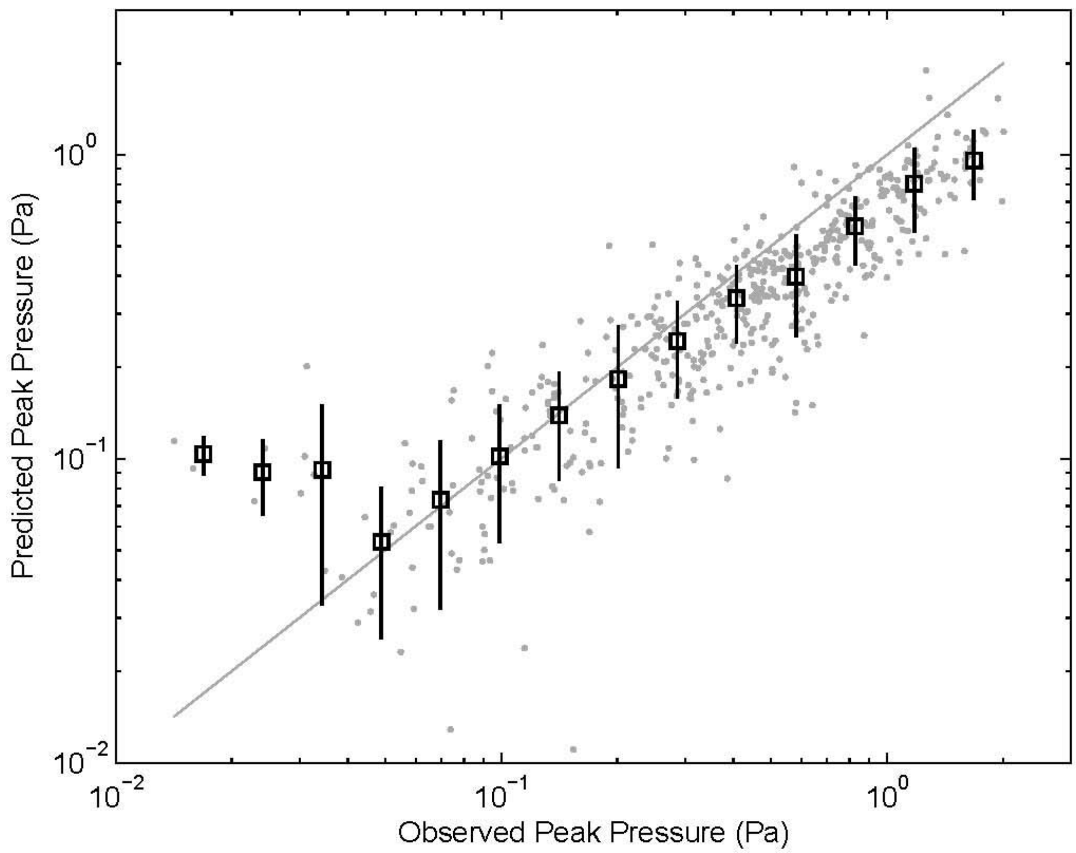

Figure 1. Comparison of data and model for peak acoustic pressure of bubbles fragmenting in fluid turbulence. Model predictions (gray dots) have been divided into observation bins. Black squares are mean levels within bins. Vertical black lines are standard errors within bins. The gray line is a 1:1 correspondance. The agreement between theory and experiment is good over most of the range and poor at low pressures.

The results from the scale model tank experiment to study surface gravity wave focusing are shown in Figure 2. Surface waves were generated at one end of a 30 meter long tank and used to focus 200 kHz pulse transmissions.

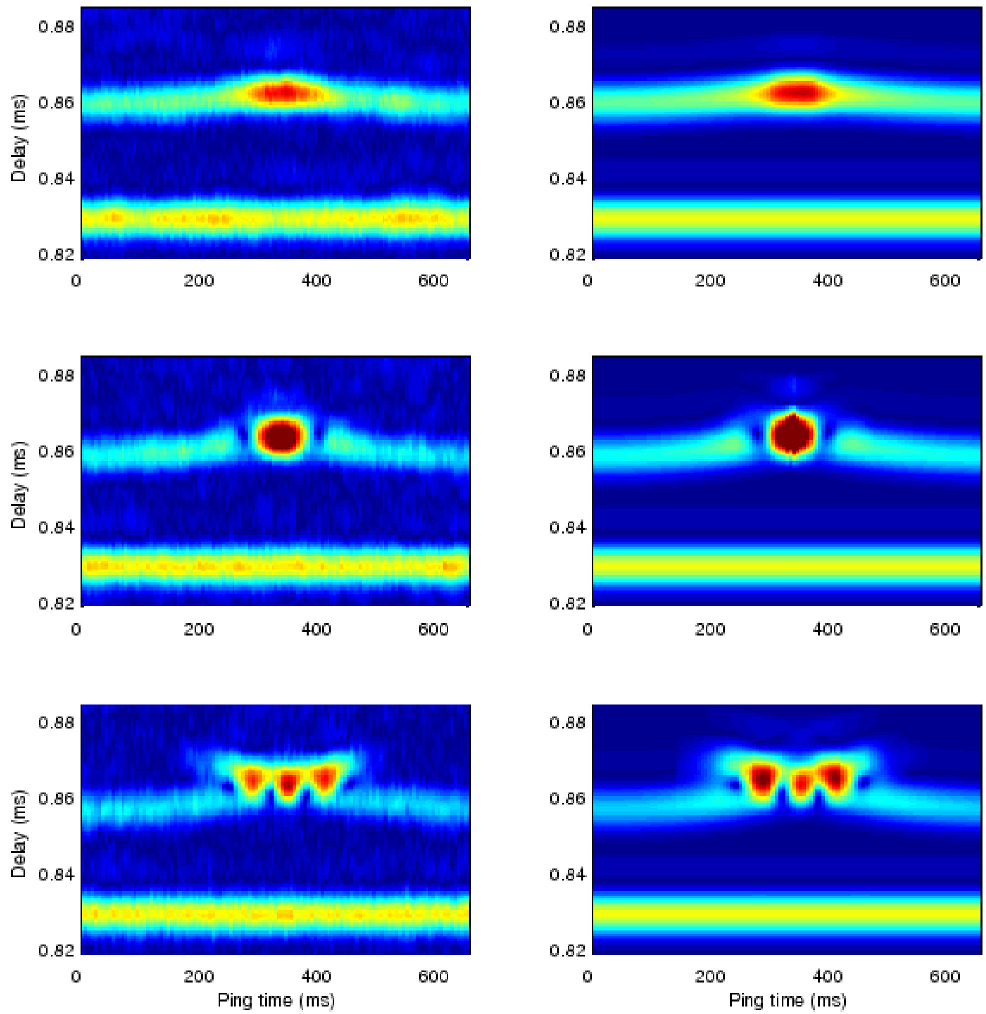

Figure 2. Model and theory for wave focussing in a 30m wave tank. The vertical panes on on the left show pulse amplitude versus delay time and ping time for 3 wave heights. The vertical panes on the right show model calculations based on a wavefronts model developed by Chris Tindle at the University of Auckland, New Zealand. The red regions correspond to focused arrivals, which are reproduced in detail by the wavefronts model.

The SPACE08 experiment at Woods Hole was successfully executed during the months of Oct. and Nov. 2008. A surface-following frame to measure bubbles within white caps, a bottom-mounted ambient noise array, two FSI acoustic wave gauges, an array of 3, 11-m long capacitive wire wave gauges, and a high-definition surface monitoring camera system were successfully deployed and recovered. In addition, the SIO science team provided all the logistical diving support for all participating institutions.

A preliminary stage of the vector sensor performance study was completed. Controlled laboratory and tank tests revealed 6 classes of error in the VS205 sensor elements. Some of these issues were already known to Wilcoxon and have been fixed for the VS300 and later sensors. Some errors remain unresolved at this time and are the subject of ongoing discussions with Wilcoxon. Eight sensor elements were deployed for 48 hours in the shallow waters north of Scripps pier on La Jolla Shores

beach. The sensors were buried in 10 cm of sediment to reduce strum and flow noise. A short segment of acceleration time series from the 8 elements is shown in Figure 3.

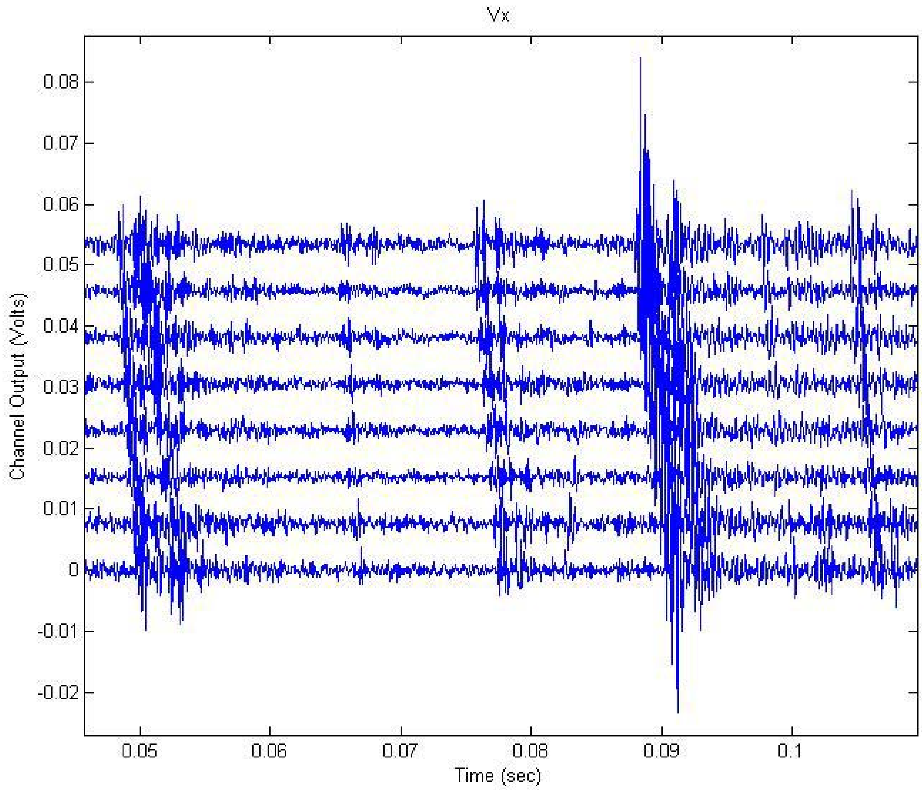

Figure 3. Vector sensor data from a deployment in the surf zone just north of the SIO pier, La Jolla Shores Beach, California. The blue lines show acceleration time series data on all 8 sensors deployed. Data plots have been offset in the vertical to provide channel discriminations, and has been high-pass filtered at 100 Hz. Simultaneously coincident, broad-band arrivals can be seen from snapping shrimp living on the SIO pier pilings.

RESULTS

There is good evidence that we have developed a model for the acoustic excitation mechanism of bubbles fragmenting in fluid sheer. This model is currently being used as part of a physics-based explanation for breaking wave noise which will help us understand the creation rate of bubbles at the ocean surface.

The laboratory experiments to study wave focusing have validated the fidelity of the wavefronts acoustic model developed by Tindle at the University of Auckland, New Zealand (Tindle and Deane 2005, Tindle, Deane and Preisig 2008).

As the SPACE08 experiment was completed only a few weeks ago, it is too early to draw any conclusions from the data collected.

With regard to the Vector sensor performance studies, initial laboratory and field tests have revealed a number of issues related to the quality of sensor navigational data, digital transfers and some of the analogue channels. We are working with engineers at Wilcoxon to resolve these issues.

IMPACT/APPLICATIONS

Having developed an understanding of the mechanism exciting sound production from bubbles in white caps will allow us to create a quantitative model for white cap noise and air entrainment rates at the ocean surface. This has a number of important military and civil applications, including characterizing ocean surface scattering, and building improved models of bubble-mediated gas flux and marine aerosol production.

Validation of the wavefronts acoustic propagation code will have important implications for the analysis of SPACE08 acoustic transmissions, and ultimately the design and performance of front/end equalizers in underwater acoustic modems.

RELATED PROJECTS

"Underwater Acoustic Propagation and Communications: A coupled research program", funded under the Multidisciplinary University Research Initiative (MURI) by ONR.

PUBLICATIONS

Deane, G.B. and H. Czerski. 2008. A mechanism stimulating sound production from air bubbles released from a nozzle. JASA express letters. 123. EL126-EL132 [published, refereed]

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